SCIENCE

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THE WORK OF THE U. S. GEOLOGICAL SURVEY.[1]

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Organization.

UNDER statutory provisions, it is the function of the Geological Survey to classify the public lands and examine the geologic structure and the mineral resources and products of the national domain, and to prepare a geologic map of the United States.

When the bureau was instituted in 1879, it was organized into a number of geologic divisions by the first director, Mr. Clarence King. Work was at once commenced in western States and Territories in several localities selected by reason of great mineral wealth or special scientific interest.

It was found at the outset that there were no adequate maps of the regions selected for survey; and it soon became evident that the geologic work could not be carried on without maps showing the relief of the land as well as the hydrography and culture. Accordingly, topographic surveys were instituted in each of the regions selected for examination. At first these surveys were planned to meet immediate needs, and the methods of mapping were not systemized or unified; the scales were diverse and the methods various, the areas were selected by geologic needs and were not fitted to a general scheme for the geologic map of the country, and the resulting maps were discordant in their conventions. At this stage the topographic surveys were executed under the direction of the chiefs of the geologic divisions. After two or three years of trial this form of organization was found unsatisfactory, and the topographic surveys were separated from the geologic work and assigned to a geographic division, which has ever since been maintained.

When the bureau was created, the science of geology was less specialized than to-day, and the geologists assigned to the different divisions were individually charged with the duties of identifying fossils, making analyses and assays, recording mineral statistics, and other collateral work, in addition to their areal and structural surveys; but, with the expansion of the several divisions, the different lines of work were gradually differentiated in each, so that each chief geologist employed assistants charged with special work; and still later it was found more economical to separate the collateral work for the entire survey, and to assign it to special divisions. In this way a division of chemistry and physics, a division of mining statistics and technology, and several divisions of paleontology were created and have since been maintained.

In the beginning the geologists commonly made their own drawings and constructed their own geologic maps; but with the extension of the work it was found better to assign all such mechanical work to skilled draftsmen; and still later it was found more economical to concentrate the work of this character in a division of illustrations.

Under the comprehensive plan for the construction of a geologic map of the United States, the topographic surveys were planned to yield atlas-sheets of uniform character, so related as together to make up a great map of the national domain. At first these atlas-sheets were engraved under contract through the Public Printer; but it was subsequently ascertained by experiment that the engraving could be executed at much less cost in the office of the Geological Survey, and an engraving division was instituted and is still kept up.

Thus the principal branches of work in the bureau are (1) the geologic survey proper, including the examination of the public lands and the study of mineral deposits as well as the preparation of the geologic map; (2) a topographic survey, designed as a basis for the geologic map of the United States; (3) paleontologic researches, designed primarily to aid geologists in the identification and classification of rock formations and mineral deposits, and incidentally to increase knowledge of past life upon the earth; (4) the collection and publication of mineral statistics; (5) the chemical and physical examination of ores, rocks, and other mineral substances; (6) the preparation of special charts and other illustrations for reports; and (7) the engraving of topographic and geologic maps. Clerical, editorial, and other lines of work are also carried on.

[1] Read before the Geological Society of America at Ottowa, Dec. 30, 1892.

Current Work.

Three principal lines of work are carried on, to which the other lines are collateral. Foremost among these is the geologic survey proper, which is made with a view to the preparation of the geologic map of the United States; but this work can be carried forward only in those areas in which the second principal line of work, i.e., the topographic survey, is completed. The third principal line is the collection and publication of information concerning the mineral resources and mining products of the country.

In describing the work of a scientific institution it is necessary to distinguish two stages in the development of scientific work, viz., the preliminary, or experimental, or preparatory stage, and the final or effective stage. During the first stage methods are devised, experiments are conducted, scientific apparatus is invented and subjected to trial, and the plan for the work is formulated; during the second stage the methods and apparatus are practically employed and the plans are carried out. Thus the first stage is that of research, more or less recondite according to the character of the work, the second stage is that of applied science; and since it is the highest function of systemized knowledge to promote human welfare, the first stage represents the seed-time, the second the harvest-time of science.

Now, in classing the work of scientific institutions by these stages, it is to be observed that the stages are unequal in all cases and dissimilar when different cases are compared: Thus, topographic surveying may be considered as an art and the methods and apparatus already known may be employed without research into principles or the development of new methods, or the art may be considered incomplete and new principles and methods may be developed from research and experiment; while geodesy always involves research concerning principles, which, in turn, affects methods. So, too, geologic surveys might be taken to represent applied science, and geologic tryos might be sent over the land to plat dips, strikes and outcrops, and to construct simple and primitive geologic maps adapted to the needs of the preceding generation; but it is the honor of geology that geologic surveys have commonly begun their work by researches relating to their special fields, and have thus advanced the science and subserved the needs of their own contemporaries and the coming generations. Again, simple land surveys represent art or applied science alone, while the natural history surveys sometimes conducted by States represent nearly pure research. In brief, it may be said that the proportion of research to effective work increases with the complexity of the branch of knowledge to which it pertains. So in the three principal lines of work in the Geological Survey, the collection of information concerning mineral resources and mining products is a statistical work involving no research and little experiment; the topographic survey might have been conducted by old methods and apparatus without research and experiment, but since these were expensive and dilatory, considerable preparatory work became desirable; while the geologic survey required a vast amount of research and experiment for the purpose of developing a sat-

isfactory classification of rocks and a satisfactory system of mapping. These conditions, in connection with the conditions growing out of the changes in the organic law of the bureau, have determined the character and progress of work in the Geological Survey.

The work of collecting mineral resources has been steadily carried forward, and it has been found thereby that the mineral production of the country has more than doubled within the thirteen years since the institution of the Survey, and that many new resources have been discovered and utilized. The statistics are collected with care by means of an elaborate system of correspondence and collaboration, and are published in a series of annual volumes. The annual mining product of the country has now reached the value of six hundred and fifty million dollars. The products form the basis for many of our industries and a large proportion of our commodities, and give employment to a great part of our population. Thus a principal source of our national prosperity is made public and rendered available for further development through this part of the work of the Geological Survey.

At first the art of topographic surveying was imperfect and the work was slow and expensive. Accordingly, experiments were conducted in different types of country, with different kinds of apparatus, and with different men and methods; and, after determining the best methods and apparatus for each part of the country, a corps of topographers was trained. This experimental stage of the work lasted four or five years, though the experiments were so conducted as to yield useful results which are incorporated in the atlas-sheets representing the general topographic survey. Some of the earlier sheets were, however, found defective, and in these cases the experimental surveys were repeated and the sheets revised. The topographic surveys have how been completed over an area of about six hundred thousand square miles, or about one-fifth of the national domain, exclusive of Alaska. The total cost, including experimental work and an extensive plant, has ranged from one dollar to fourteen dollars per square mile, averaging about four dollars. Thus it is believed that the surveys of the bureau have been more expeditious and less expensive than any other topographic surveys of equal accuracy thus far made in any country. The work is not geodetic, nor is it cadastral; yet, while it is primarily designed only as a basis for the geologic surveys and thus for the geologic map contemplated in the statute, the atlas sheets have been found useful for many other purposes. They are in constant demand by engineers, road commissioners, miners, and prospectors, and are widely accepted as the most useful bases for mining and commercial maps and school and general atlases.

When the geologic studies were commenced much of the national domain had never been examined by geologists, and thus the rock formations and mineral deposits of the country were not classified; moreover, there was no comprehensive plan for geologic mapping. Accordingly, in geology as in topography, the initial stage of the work was preparatory and was designed to develop, first, a system of classification of rocks, and, second, a system of mapping them. But, while the work was experimental, it was conducted in accordance with the best systems of classification and mapping already in vogue in this and other countries, and was thus made to yield useful results which are published in preliminary maps and reports. These preliminary results of the work are incorporated in thirteen royal octavo annual reports (of which the last three are about to leave the press), twenty quarto monographs, and one hundred octavo bulletins, in addition to seven octavo volumes of the reports of mineral resources.

By reason of the immaturity of the science, and by reason of the vast extent and complexity of the rocks of the country, the preliminary stage in this work was longer than in topography, lasting indeed ten or twelve years. Within the last two years the classification of rocks, mineral deposits, and superficial formations has been so far elaborated as to warrant use as a basis for the geologic map of the United States; and, at the same time, a system of mapping has been developed. Under this system provision is made for representing the sedimentary, igneous, and ancient crystalline formations, as well as the mineral deposits associated with each, by distinct conventions; and provision is made also for mapping the superficial formations on separate sheets in those regions in which they are well developed and of economic or scientific importance. This system of mapping has been under actual trial for two years, and is now practically applied. Over a dozen sheets have been engraved in the office of the Survey within the past year, and several others have been published or are in press, appended to reports on special regions or topics; and a still larger number are completed in manuscript. One hundred atlas-sheets representing rock formations and mineral deposits, each constituting a section of the final map, are engraved or ready for engraving; and these sheets cover an area of about 120,000 square miles, or four per cent of the national domain, exclusive of Alaska. Moreover, sixty atlas-sheets showing superficial formations have been completed in regions in which the underlying rocks are generally inaccessible and of little economic value, and these sheets cover an additional area of about 60,000 square miles. Thus the aggregate area now mapped geologically reaches 180,000 square miles, or six per cent of the national domain.

In addition to the areal surveys, important results have flowed from the researches conducted by the Geological Survey. These results are not easily stated, partly because science is not quantitative and cannot be weighed and measured in any standard units, partly because science is common property and some portion of each great result is to be credited to scientific investigators not connected with the bureau. Nevertheless, a number of valuable additions to the science of geology have been made during the past decade, largely through the labors of the able corps of experts, to whose skill, zeal, and industry the bureau owes much of its success. Among these may be mentioned, the recognition and founding of a great rock system, the Algonkian; the discrimination of glacial deposits throughout northern United States and the interpretation of the complex and wonderfully interesting history of which they are records; the discovery of the rate of seismic transmission and of other laws of earthquakes; a classification of the igneous rocks and a tentative grouping of the ancient crystallines; the development of a new division of geologic science — Geomorphy, or the New Geology — in which the past history of the earth is read from topographic forms, as formerly from formations and their fossils; and a general physical classification of the rocks of a considerable portion of the country.

The cost of the areal geologic work has ranged from less than a dollar per square mile in provinces of simple structure to fifty or sixty dollars per square mile in certain mining regions of exceptionally complex structure. The average cost, making reasonable allowance for reconnaissance, and reckoned on the basis of aggregate appropriations, is eight or nine dollars per square mile. It is to be noted that this figure includes all collateral work in paleontology, chemistry and physics, mineral resources, engraving, and miscellaneous work of all kinds, as well as the acquisition of a large library, the publication of one hundred and forty reports, the training of experts, and the purchase and maintenance of an extensive plant, together with a general reconnaissance of the country. The actual cost of the geologic surveys in two representative provinces, including field and office work as well as supervision and revision, ranges from two to three dollars per square mile. Accordingly, although the geologic work is barely past the experimental stage, the cost compares favorably with that of similar work executed in foreign countries and in our own States.

Future Work.

It is believed that the organization of the work of collecting and publishing mineral statistics is now so complete and the corps of correspondents and other collaborators so expert and zealous that this branch of the work may be carried forward more expeditiously and economically than ever before. It is the design not only to continue but gradually to expand this branch of the work, in order that it may keep pace with the increasing development of mining production, the discovery of new mineral resources, and the invention of new applications for resources already known.

While some mistakes have been made, it is believed that the topographic methods and the apparatus employed are now thoroughly effective; and that for this reason, and for the further reason that a corps of expert topographers has grown up, this branch of the work can also be carried forward more expeditiously and economically than ever before. At first most of the work was executed on a scale of four miles to the inch, another part on the scale of two miles to the inch, and only a small part on larger scales; but the improvement in methods, apparatus, and skill has been such that the surveys can be made on a scale of a mile to the inch at slightly greater cost than the original surveys on a quarter of that scale; and, accordingly, all the surveys of the bureau are now made on the two-mile scale and the one-mile scale, and the four-mile scale has been abandoned. It is proposed to continue the work on these scales, and to give such attention to minor topographic details as to yield a good topographic map of the entire country, which, while neither geodetic nor cadastral, will serve as a satisfactory basis for geologic surveys and for a wide variety of industrial purposes.

In geologic surveying, and thus in the preparation of the geologic map of the United States, the work is rapidly passing from the preliminary stage of research to the effective stage of applied science; and it is believed that the methods developed are so far satisfactory as to warrant a definite working plan for the future. This plan includes a system of rock classification and a system of map conventions based thereon by which widely applicable and useful distinctions may be made. It includes also a system of arranging the atlas-sheets constituting sections of the geologic map of the United States provided for by the statute, and the accompanying descriptive text in atlas folios designed for convenient distribution and use. Each atlas folio is inclosed in a cover bearing a suitable title and a key-map locating the atlas-sheet, and each contains a copy of the topographic sheet without geologic colors; a second copy colored by formations; a third copy colored by groups with structure sections introduced; a fourth copy colored by formations of economic value and showing also the locations of mines and industrial establishments depending on mineral resources; in the glaciated regions a fifth copy showing superficial formations and their resources; and sometimes additional sheets giving columnar sections and other illustrations of the region. The accompanying text includes an elementary explanation of the atlas, a general sketch of the geologic province, and a special description of the area covered by the sheet. Furthermore, the plan contemplates the extension of the geologic surveys from the regions of complex structure, in which the classifications were developed, into regions of simpler structure, in which more rapid progress may be anticipated. Moreover, since a corps of experts has now been trained in the methods and the classification developed in the bureau, and since these experts are now ready to extend operations into the rich mining regions and other important fields in which premature work would have been unwise, it is planned to strengthen this technical work and thus to enhance the economic value of the geologic map without detracting from its scientific character.

The purpose of our statesmen in instituting the Geological Survey was to enable those engaged in mining and related industries to exploit our mineral resources safely and economically. It has always been recognized that mineral resources depend on rock structure, and that the structure and relations of rocks cannot be made intelligible to practical men without classification; moreover, it was understood that the structure and relations of rocks cannot be described, and in some cases cannot even be ascertained, without maps. It was for these reasons that statutory provision was made for the construction of a geologic map of the United States in connection with the examination of the mineral resources and mining products; it was for the same reasons that the topographic survey was undertaken as a basis for the final geologic map. The work of the topographic branch of the bureau has passed the experimental stage and entered upon the effective stage, while the work of the geologic branch is now passing from the stage of elaborate and often recondite research to the effective stage; and it is designed to carry forward the work of both branches with energy and to proceed with the preparation of the geologic map on a basis at once thoroughly scientific and economically useful. In fact, during the past two or three years the transformation in geologic work has been in progress and is now practically accomplished. Thirteen atlas folios are now engraved, and the field-work for about 160 atlas folios is completed, while the field-work required for a still larger number is in progress. In addition to these completed surveys, a general reconnaissance has been extended over about four fifths of the entire area of the United States, and a reconnaissance map representing the results of this work is now in the hands of the engraver.

THE GEOLOGICAL SOCIETY OF AMERICA.

THE fifth annual and winter meeting of the Geological Society of America was held in Ottawa, Canada, beginning Wednesday, Dec. 28, 1892.

Through the kindness of Dr. J. G. Bourinot, C.M.G. of the Royal Society of Canada and clerk of the House of Commons the ample and commodious room of the Railway Committee of the House of Commons was placed at the disposal of the society. There were about forty Fellows present, sixteen of whom came from various portions of the United States. The meeting was under the presidency of Mr. G. K. Gilbert, Chief Geologist of the United States Geological Survey, Washington, whilst Prof. H. L. Fairchild of the University of Rochester was secretary.

If we are to judge by the attendance and interest manifested at the meeting, as well as by the grade of papers presented, there is no doubt that it was a decided success. A local committee composed of Fellows of the Royal Society, members of the Logan Club, which comprises the scientific staff of the Geological Survey of Canada, etc., had made all necessary arrangements for the comfort and lodging of the members during the meeting. Dr. Selwyn, as chairman of the committee, and Mr. Smith as secretary, spared no pains to give the visiting Fellows of the Society a good reception. Much praise is also due His Excellency the Governor General for the exceedingly kind and generous manner in which he devoted so much time and attention to the society besides furnishing the Fellows from a distance with an excellent opportunity of having a glimpse of social life at the Canadian capital by giving an "at home" at Rideau on Friday afternoon. To Dr. Ells, Mr. J. B. Tyrrell and others, much credit is due for their exertions in preparing matters.

Shortly after ten o'clock on Wednesday, the 28th, President Gilbert took the chair and called upon His Excellency the Governor General to give the address of welcome. His Excellency made a very neat address which was received enthusiastically. To this the president replied, and referred to the proverbial hospitality for which Canadians were noted. The report of the Council was then presented by the secretary and the result of the vote announced so far as conclusions were arrived at. The following leading officers were then declared elected: President, Sir J. William Dawson; secretary, Prof. H. L. Fairchild; treasurer, Dr. T. C. White. The Secretary's report, as well as that of the treasurer, showed the society to be in a flourishing condition. Then followed obituary notices of three deceased Fellows: T. Sterry Hunt, J. S. Newberry, and J. H. Chapin. Prof. Raphael Pumpelly's notice of Dr. Hunt was read by Mr. Van Hise; that of Prof. Newberry, prepared by Dr. Kemp, was read by Prof. H. L. Fairchild; and Prof. Hitchcock read W. M. Davis's memorial of J. H. Chapin.

The reading of papers or work proper of the society began Wednesday afternoon at 2 P.M. Below is a list of the papers, in the order in which they were taken up at the meetings. The whole time of the society was taken up reading and discussing papers until a late hour Friday, the 30th of December. Time and space do not allow us here to do justice to the interesting discussions on the papers presented. Both Glacial and Archæan geology received a goodly share of animated discussion, whilst a few papers on palæontology also stimulated further inquiry. Dr. Willard Hayes's paper on "The new geology" was a splendid contribution to the geomorphology of the district examined by that author and described by him.